2005 Shellfish Survey of Potter Pond
South Kingstown, Rhode Island

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Introduction

In July 2005, the Rhode Island Senate passed Resolution S 1228, entitled "Senate Resolution Respectfully Requesting the Department of Environmental Management to Undertake a Study of All Aspects of the Taking of Shellfish with the Use of Diving/Breathing Apparatus in Salt Ponds." In response, the DEM's Division of Fish and Wildlife, Marine Fisheries Section, conducted a limited shellfish survey in Potter Pond, South Kingstown, RI during late August and early September 2005. The survey was reduced in scope over that originally contemplated since funding and staff time were limited. The Division then evaluated the survey results, considered outcomes, and reviewed some management options. This report summarizes those efforts.

Survey Methods

Potter Pond was selected for the survey for several reasons, including the existence of a historical database, recent user conflicts between divers and local residents, and the proximity of the pond to the DEM's Coastal Fisheries Laboratory in Jerusalem. The Senate Resolution called for a generic "study," encompassing (presumably all of) the salt ponds. However, due to the lack of dedicated funding, the Division of Fish and Wildlife narrowed the scope and magnitude of the assessment work to a replication of the resource survey performed in Potter Pond in 2000. As a designated Shellfish Management Area, Potter Pond is typical of other southern RI salt ponds. Thus, the survey findings are likely to be representative of conditions in other ponds.

Soft-shell clams, *Mya arenaria*, are the dominant shellfish species in Potter Pond. They are also the dominant species in some of the other southern RI salt ponds. A depiction of their life cycle is given in Figure 1. Spawning typically occurs in June. The larvae remain planktonic for a short period of time before settling to the bottom and burrowing into the sediment.

Based upon the survey performed in 2000 (Ganz et. al. 2000), seven survey zones were established in Potter Pond, all of which are subject to commercial shellfishing pressure. The seven zones comprise a total area of approximately 15 acres. Representative sample stations within each zone were established and demarcated with latitude and longitude coordinates (Table 1). A 16-foot outboard-powered research skiff was used to transport personnel and equipment to each sample station, and a WAAS-enabled handheld GPS was used to locate each station. A one-square meter steel frame attached to a float was thrown into the water randomly at each station. SCUBA divers, using a suction sampling device powered by an engine-driven pump, excavated each square meter to a minimum depth of 12 inches or to solid rock. All materials collected by the suction sampling device were collected in a nylon mesh bag and brought to the research vessel and, depending upon the amount collected, back to the Jerusalem Lab for analysis. The substantial amount of material and shellfish present in some stations required sub-sampling to provide length and density information. Additionally, the total number of stations sampled was reduced from the original study design because of the amount of time required to process each sample. A total of seventeen representative one-square-meter samples were taken within each of the seven zones. Visual substrate surveys were made using SCUBA to estimate the extent of habitat within each zone. Maptech "Terrain Navigator Pro" software was used to draw the limits of each zone, estimate the total area of each zone, and produce the map in Figure 2. The soft-shell clam sample densities were expanded over each zone to estimate the number of clams in the entire 15-acre sample area.

Survey Results

Sample results by station are given in Table 2. As expected, soft-shell clams were the most abundant shellfish species sampled in the survey. Soft-shell clams in Potter Pond follow the typical pattern of a patchy distribution; as a result, some stations had low densities while others had very high densities. The geometric mean density of clams in the sampled areas was 166 per square meter with a 95% confidence bound of 46-593. The length-frequency distribution by age, of all the soft-shell clams sampled in the study area is depicted in Figure 3. Estimates of the number of individual soft-shell clams by age, and estimates of the number of bushels of legalsized clams (1627.25 bushels) in the 15-acre study area are shown in Table 3. Areas in the pond that were not surveyed are likely to hold significant numbers of clams as well. More detailed analyses of size composition, mortality rates and biological reference points are found in Appendix A. Soft-shell clam abundance in Potter Pond is at an all-time high (see Figure 8), which is consistent with a trend seen throughout Narragansett Bay. Fishing mortality rate in the pond is below but close to the over-fishing threshold. Over-fishing is not yet occurring but continued monitoring is recommended. Current conditions of high juvenile clam production are resulting in the rapid replacement of clams that are removed by fishermen. These findings do not rule out the possibility of localized depletions, and they certainly do not dismiss the occurrence of user conflicts in specific areas.

Fishing Activities

The high abundance and productivity of the soft-shell clam resource in Potter Pond has triggered increased commercial interest and activity, which is consistent with statewide trends. Since 2000, commercial landings of soft-shelled clams have increased threefold in Rhode Island (Figure 8). There is a statutory prohibition on the use of SCUBA to harvest shellfish in Potter Pond, as well as Green Hill, Charlestown (Ninigret), and Quonochontaug Ponds. Current commercial activity in the ponds includes shore digging, boat harvest, and diving with air supplied by compressors. The latter technique involves hand collection of shellfish; the supplied air is not used to manipulate the substrate. (Mechanical dredging of shellfish is illegal in RI waters.) Shore digging by recreational fishermen is also a common practice in the ponds. Commercial fishing activities by supplied-air divers in Potter Pond have generated concerns on the part of some local residents in recent years. It appears that these concerns are attributable to user conflicts, as there is no indication based on this survey that the commercial harvesting activities have caused over-fishing to occur. The reported user conflicts may be based on the high density of soft-shelled clams around the perimeter of the pond, which attracts commercial shellfishermen and puts them in close proximity to abutting landowners and recreational boaters.

Current Management Program

Potter Pond is an established Shellfish Management Area (reference: section 3.6.6 of the RI Marine Fisheries Regulations). The current harvest limits in Shellfish Management Areas are as follows:

Boat Harvest

R.I. Resident (recreational/no sale)	1 peck/day/person
R.I. Resident (commercial)	3 bushels/day/license holder; maximum of 6 bushels/boat/day; and maximum of two licensed shellfishers per boat
Non-Resident (recreational/no sale)	½ peck/day/license holder

Shore Digging

R.I. Resident (recreational/no sale)	1 peck/day/person
R.I. Resident (commercial)	3 bushels/day/license holder
Non-Resident (recreational/no sale)	½ peck/day/license holder

Discussion/Management Options

At this point, current regulations would appear to be sufficient to maintain a sustainable soft-shell clam fishery in the salt ponds of southern RI, including Potter Pond on a pond-wide basis. Given the recent reported increase in commercial activity, however, regular monitoring and surveys are warranted in all Rhode Island waters, including Potter Pond. DEM's Division of Fish and Wildlife (DFW) will continue to conduct annual resource surveys, with the caveat that such work will be based on available resources and undertaken in accordance with a rotating schedule of surveys covering shellfish management area throughout the state. Moreover, the Division is improving the State's fishery monitoring program through implementation of the new electronic, dealer-based reporting system (known as SAFIS). Together, these programs will greatly improve management of shellfisheries in the state by providing more spatially explicit (and harvest-method explicit) information on fishery landings and shellfish abundance.

To offset increases in fishing pressure that might threaten the shellfish resource in Potter Pond in the future, it might be reasonable to consider instituting additional management measures. One possibility is the establishment of a spawner sanctuary. These are areas where broodstock are allowed to replenish populations in fishable areas, and in addition to rotational harvest beds, are fundamental elements of DEM's Shellfish Management Plan. They have been employed at various locations in Narragansett Bay and other coastal ponds, with good success. Pollution closures essentially double as spawner sanctuaries and thus also contribute to the maintenance of sufficient spawner biomass. Potter Pond has no closed areas due to pollution, nor any established spawner sanctuaries. Designating one or more sites as sanctuaries would provide added resource protection and further contribute to resource stability. The proper siting of a sanctuary – based on pond circulation patterns and other environmental determinations – would be necessary in order for it to be effective. Other management measures that might be considered include open/closed seasons, reduced bag limits, or reductions in allowable fishing days or allowable hours per day. These are also regular features of the current DEM/DFW quahog management program.

The user conflicts involving divers and local residents are difficult to address on a resource limitation basis. Traditionally soft-shell clams are harvested in mud flats exposed at low tide. The clams sampled in Potter Pond were all found in water 3 feet deep or greater and never exposed at low tide. Because these clams are permanently submerged, they are probably not subject to much recreational fishing pressure. Supplied air diving is the most effective method to access these clams. Supplied air diving is also an efficient technique, and it has conservation benefits. Hand-fanning the sediment and selectively choosing legal-sized clams from the beds, while protecting undersized clams, can be very productive and, at the same time, protective of the resource. Use of rakes (hand rakes or bull rakes) is less efficient and generates lower yield because of damage to clams indiscriminately cracked and exposed to predation. Further loss is probable as small juveniles may be reburied too deeply to survive during the harvest process.

Some of the potential resource management options, discussed above, might also help to reduce user conflicts. For example, limiting commercial harvesting to certain seasons during the year, and/or days during the week, and/or times during the day, would potentially mitigate some of the concerns expressed by local residents, while allowing a certain baseline level of commercial activity to continue. Another reasonable way to address the conflict issue is to consider restrictions based on public safety concerns. Such concerns are clearly valid, since much of the diving activity takes place near private docks. Such activity limits the ability of shorefront property/dock owners to use their boats, and worse, creates the potential scenario of propellers engaging in close proximity to divers. Enacting a prohibition against diving activities that impede access to or departure from a dock (or mooring) might be a sensible way to address the legitimate safety concerns associated with certain aspects of current shellfishing operations undertaken by divers.

Conclusions

The soft-shell clam resource in Potter Pond appears to be in a condition of sustainable harvest. No evidence of over-fishing was found and abundance was high. Traditionally soft-shell clams are harvested in mud flats exposed at low tide. The clams sampled in Potter Pond were all found in water 3 feet deep or greater and never exposed at low tide. Because the clams in the sample areas are permanently submerged, they are not likely to be targeted by recreational shellfishermen. Use of rakes (hand rakes or bull rakes) is a potential harvest method in the sample areas; however, the technique would cause many clams to be indiscriminately cracked and exposed to predation, and further cause juveniles to be reburied too deeply to survive during the harvest process. Supplied air diving is the most effective, and least destructive, method to access the permanently submerged clam stocks. If soft-shell clam harvesting is to continue, hand-fanning the sediment and selectively choosing legal-sized clams from the beds, while protecting undersized clams, is the best method to insure a self-sustaining fishery.

Current regulations appear to be sufficient to maintain a sustainable soft-clam fishery in Potter Pond on a pond-wide basis. Continued assessment work and improved monitoring will be necessary to maintain an effective management program. Recent increases in fishing pressure might warrant the institution of additional management measures to help protect the resource and sustain the fishery. Options include the establishment of one or more spawner sanctuaries, open/closed seasons, reduced bag limits, or reductions in allowable fishing days or allowable hours per day.

Issues between commercial shellfishermen and the abutting landowners in and around Potter Pond are the result of user conflicts rather than over-fishing. Some of the potential resource management options might also help to reduce user conflicts. For example, user conflicts may be reduced if commercial harvest were permitted during specific periods for a limited number of days. In certain Narragansett Bay shellfish management areas, harvest of shellfish is limited to Monday, Wednesday, and Friday from 8:00AM until Noon with a 3 bushel daily harvest limit This minimizes user conflicts during peak boating periods while providing commercial fishing access to shellfish resources. Another alternative would be to establish a fishing season, which would restrict commercial harvest to times of reduced recreational boating pressure (e.g., September through May). Eliminating the air-assisted harvest techniques as an alternative would likely increase fishery mortality, with decreased harvest success, as bull raking would remain as the only deep-water option. To help protect public safety, it might be worth considering a prohibition against diving activities that could impede access to or departure from a dock (or mooring).

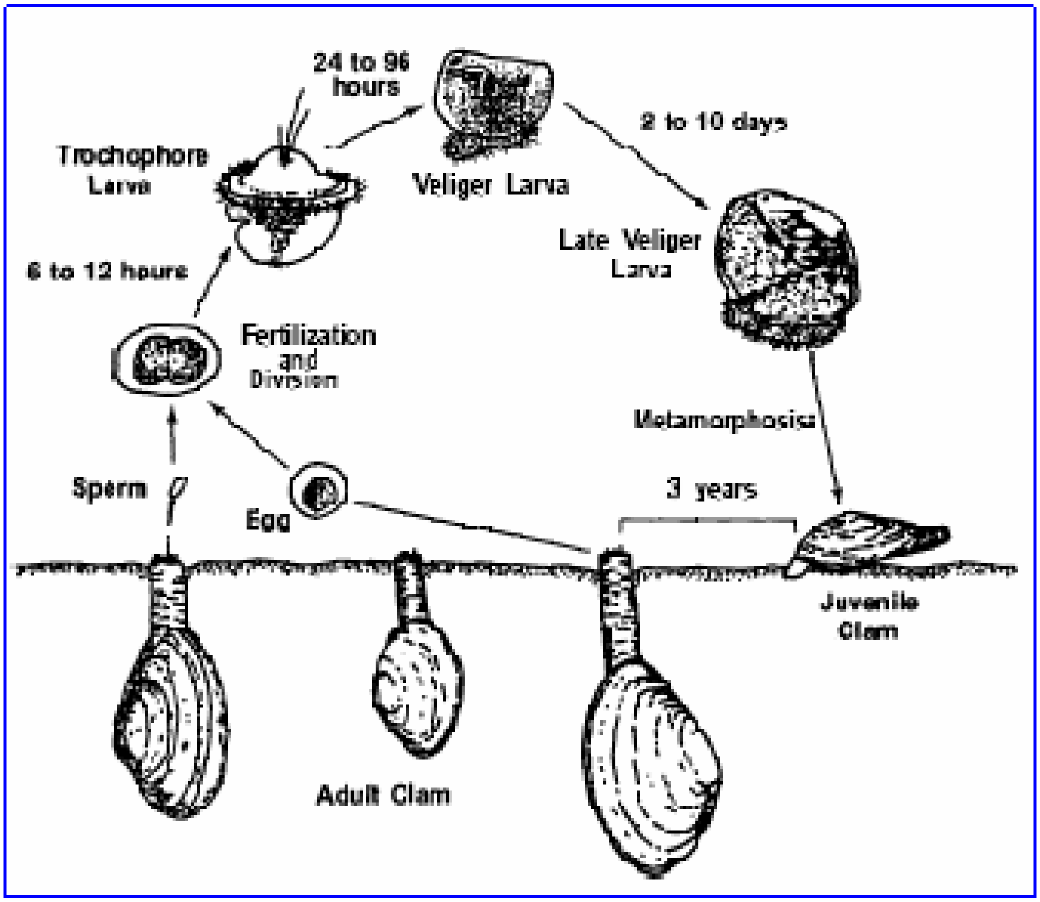
Ultimately, the most effective way to address the user-conflict issue might be to enhance public education and awareness regarding the status of the resource, as borne out by this survey and future survey and monitoring activities, as well as the nature of the air-supplied commercial harvesting activities. Some local residents in the Potter Pond area may not be aware that the diving operations: 1) do not involve the use of air to manipulate the substrate; 2) are more protective of the resource than use of bull rakes; and 3) generally target permanently submerged areas, rather than areas exposed at low tide. DEM would welcome the opportunity to facilitate and/or join in meetings or workshops where these and other issues could be discussed and evaluated.

TABLE 1.

Potter Pond Shellfish Survey 2005 Station Locations

STATION	LATITUDE	LONGITUDE
A	41^o 23' 53.8"	71^o 32' 16.9"
B	41^o 23' 48.1"	71^o 32' 06.4"
C	41^o 23' 49.8"	71^o 32' 17.9"
D	41^o 23' 48.9"	71^o 32' 19.3"
E	41^o 23' 47.7"	71^o 32' 22.5"
F	41^o 23' 42.6"	71^o 32' 24.7"
G	41^o 23' 38.6"	71^o 32' 22.8"
H	41^o 23' 38.6"	71^o 32' 22.8"
I	41^o 23' 37.1"	71^o 32' 03.8"
J	41^o 22' 57.2"	71^o 31' 58.8"
K	41^o 22' 58.2"	71^o 32' 08.2"
L	41^o 23' 01.8"	71^o 32' 27.3"
M	41^o 22' 51.2"	71^o 32' 28.1"

FIGURE 1.



Mya arenaria, Soft-Shell Clam Life History - USFWS.

FIGURE 2.

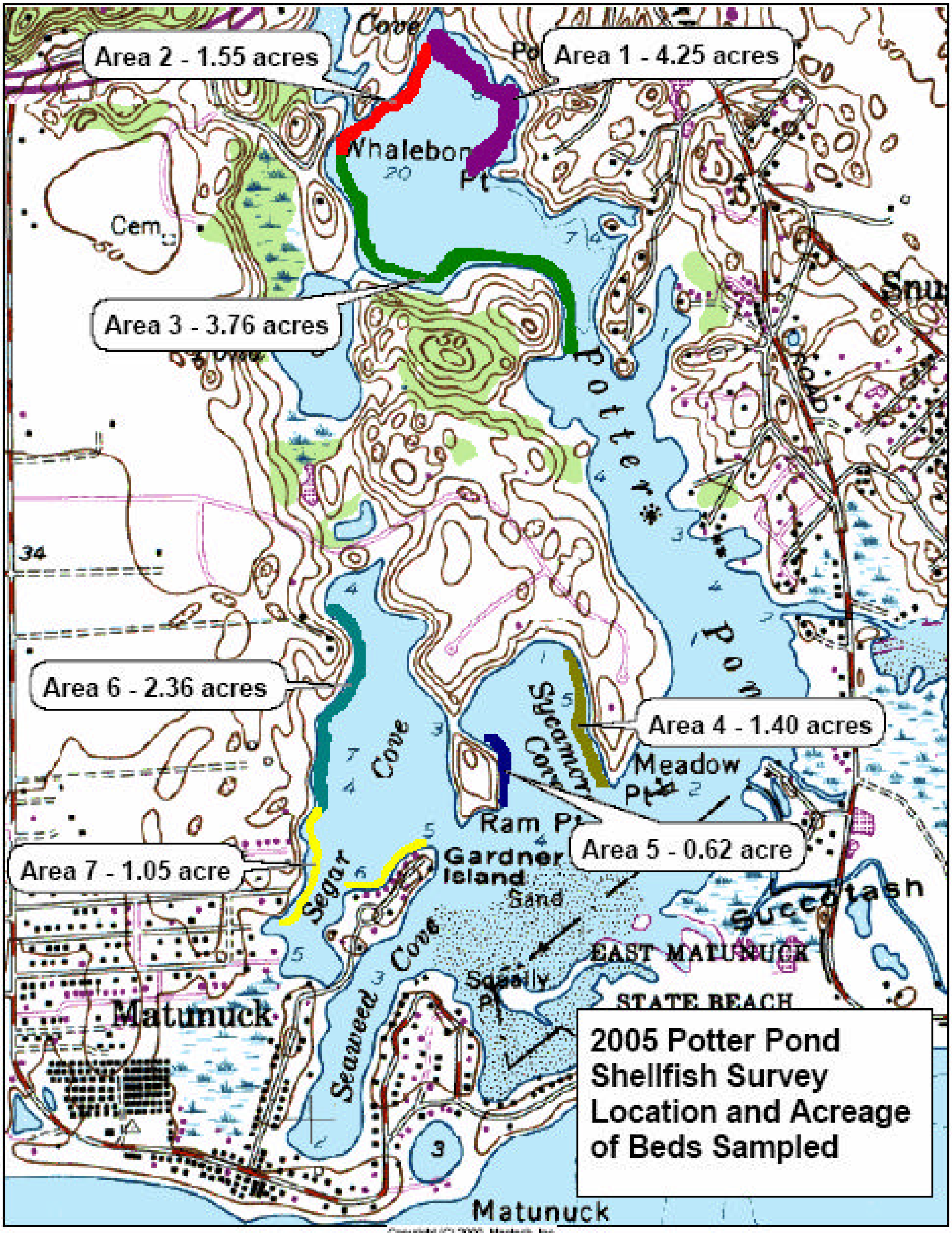

Area 2 - 1.55 acres
Area 1 - 4.25 acres
Area 3 - 3.76 acres
Area 6 - 2.36 acres
Area 4 - 1.40 acres
Area 5 - 0.62 acre
Area 7 - 1.05 acre
Whalebone Pt
Cem
Potter Pond
Sycamore Cove
Meadow Pt
Ram Pt
Gardner Island
Sand
Segar Cove
Seaweed Cove
Succotash
EAST MATUNUCK
STATE BEACH
Matunuck
2005 Potter Pond
Shellfish Survey
Location and Acreage
of Beds Sampled

TABLE 2.

		A	B	C	D	E1	E2	E3	F	G	H	I	J	K	L1	L2	L3	M
		STATIONS																
	0.25 YEAR	**0**	**0**	**11**	**386**	**288**	**245**	**0**	**364**	**116**	**274**	**784**	**0**	**8**	**31**	**3188**	**33**	**6953**
AGES	**1.25 YEARS**	**0**	**0**	**5**	**436**	**141**	**120**	**0**	**180**	**253**	**141**	**15**	**0**	**3**	**11**	**258**	**457**	**175**
	2.25 YEARS	**0**	**0**	**0**	**53**	**120**	**56**	**1**	**83**	**86**	**17**	**12**	**0**	**58**	**1**	**86**	**128**	**432**
	>/= **3.25 YEARS (LEGAL)**	**1**	**1**	**0**	**101**	**137**	**139**	**6**	**187**	**73**	**51**	**4**	**0**	**22**	**0**	**17**	**144**	**154**

NUMBER SOFT-SHELL CLAMS PER METER^2 BY AGE AND STATION

FIGURE 3.

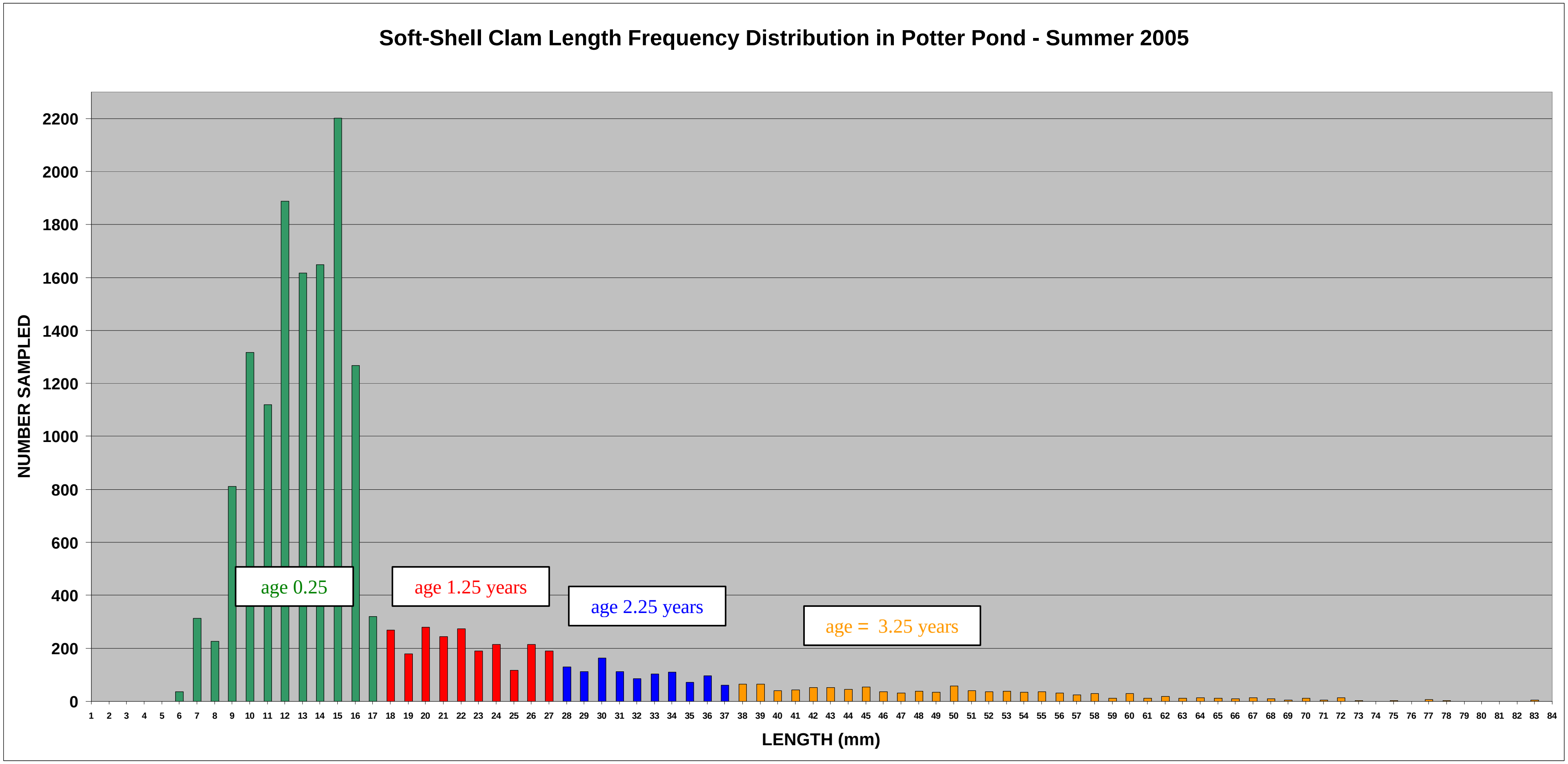

Soft-Shell Clam Length Frequency Distribution in Potter Pond - Summer 2005
NUMBER SAMPLED
LENGTH (mm)
age 0.25
age 1.25 years
age 2.25 years
age = 3.25 years
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

TABLE 3.

POTTER POND 2005

ZONE	ACREAGE	METERS^2	STATIONS	SUBLEGAL # AGE 0.25	ESTIMATED # AGE 0.25 BY ZONE	SUBLEGAL # AGE 1.25	ESTIMATED # AGE 1.25 BY ZONE	SUBLEGAL # AGE 2.25	ESTIMATED # AGE 2.25 BY ZONE	LEGAL # AGE =3.25	ESTIMATED # AGE =3.25 BY ZONE	TOTAL # PER	UNITS	SUBBSTRATE TYPE / RATING
AREA 1	4.25	17,199.14	A,B (2 m^2)	54		3		0		2				ROCKS, MUD / POOR
				27	464,376.78	1.5	25,798.71	0	0.00	1	17,199.14	**29.50**	**1 m2**	
AREA 2	1.55	6,272.63	C1,C2,C3,D,E (5 m^2)	931		702		230		383				ROCKS, SAND, MUD, FAIR
				186.20	1,167,963.71	140.40	880,677.25	46.00	288,540.98	76.60	480,483.46	**449.20**	**1 m2**	
AREA 3	3.76	15,216.18	F,G,H,I (4 m^2)	1538		590		198		315				SAND, MUD, GOOD
				384.50	5,850,621.21	147.50	2,244,386.55	49.50	753,200.91	78.75	1,198,274.18	**660.25**	**1 m^2**	
AREA 4	1.4	5,665.60	J (1 m^2)	0	0.00	0	0.00	0	0.00	0	0.00	**0.00**	**1 m^2**	ROCKS, SAND / POOR
AREA 5	0.62	2,509.05	K (1 M^2)	8	20,072.40	3	7,527.15	58	145,524.90	22	55,199.10	**91.00**	**1 m^2**	MUD / POOR
AREA 6	2.36	9,550.58	L1,L2,L3 (3 m^2)	3252		737		215		161				SAND, MUD, GOOD
				1084.00	10,352,828.72	245.67	2,346,259.15	71.67	684,458.23	53.67	53.67	**1,455.00**	**1 m^2**	
AREA 7	1.05	4,249.20	M (1 m^2)	6953	29,544,687.60	175	743,610.00	432	1,835,654.40	154	654,376.80	**7,714.00**	**1 m^2**	SAND, MUD, EXCELLENT
TOTAL	14.99	60,662.38								386.02	**1,562,154.08** LEGAL PER 15 ACRES			

1 acre is equal to 4,046.86 square meters

17 M^2 SAMPLED

25.75 PER M^2

120 **COUNT PER PECK/GALLON 2 INCH CLAMS**
960 **COUNT 50MM CLAMS PER BUSHEL**

25.75161219

60,662.43 **25.75 LEGAL CLAMS = 38MM LENGTH PER METER^2**

14.99 ACRES = 60662.43 SQUAR **1,562,155.41 ESTIMATES LEGAL SIZED CLAMS IN COMBINED 7 ZONES**

1 acre is equal to 4,046.86 squa **1,627.25 ESTIMATED TOTAL NUMBER OF BUSHELS LEGAL SIZED CLAMS IN 7 ZONES**

MEAN SIZE OF ALL LEGAL-SIZED CLAMS SAMPLED 50.15MM

Appendix A- Technical Supporting Material

Rhode Island Soft-shell Clam Growth Rates and Cohort Slicing- Appledorn (1982) conducted extensive research on the growth rates of soft-shell clams, *Mya arenaria*, along the Atlantic coast of Canada and the United States. Seven sampling stations in Rhode Island were included in his latitudinal study of *Mya* growth rates. Stations were located in both Narragansett Bay and the Rhode Island coastal salt ponds. Appledorn decomposed *Mya* length frequency distributions into age distributions using a computer-assisted method of fitting mixtures of normal curves. Rhode Island age-length data from his dissertation were extracted, pooled and used to fit a von Bertalanffy growth curve of the form:

$$L_t=L_\infty (1-\exp(-k(t-t_0))) \qquad (1)$$

where: L= shell length in mm
t= age in years
L_∞= asymptotic length parameter
k= growth coefficient
t_0= age at length equal zero.

Most of Appledorn's clams were age 1 or older. Additional observations for very small clams sampled during the Greenwich Bay fish kill in August of 2003 and assumed to be young of the year (YOY) were added to provide better curve resolution near the origin. All data and the SOLVER fitted curve are plotted in Figure 4. Parameter estimates to eq.1 were L_∞ = 86.0 mm, k = 0.19 per year and t_0 = -0.51 years. Eq.1 can be algebraically re-arranged to solve for age (t) given the parameter estimates for L_∞, k, and t_0. The soft-shell clam length frequency from 2005 Potter pond sampling was transformed into an estimated age distribution by solving each 1mm length group for age and accumulating ages by 1 year intervals. For comparative purposes, Potter Pond length samples from 2000 were similarly analyzed (Ganz et al. 2000).

Estimates of Total Mortality Rate from Age Composition- We applied the cross sectional catch-curve method of Ricker (1975) to estimate total mortality rate (Z) from the estimated age distributions. Assuming that mortality of cohorts of animals follows the exponential decay law, total mortality rate can be estimated from a regression of the logarithm of abundance at age on age for the fully recruited (legal) age groups:

$$\ln(N_a)= \ln(N_0)-Z*a \qquad (2)$$

where: N= abundance
a= age
N_0= initial abundance
Z= total instantaneous mortality rate per year.

Appledorn's findings show that soft-shell clams in Rhode Island reach the 38 mm minimum size limit at age three so the catch-curve regressions were applied to ages three and older. The estimated Potter Pond age distribution and fitted catch curve are plotted in Figure 5. The regression slope (Z) was estimated at 0.49 with a standard error of 0.03. A comparable value for the 2000 Potter Pond sample was 0.47 (0.06). A catch curve regression applied to the pooled age structure for Rhode Island clams in 1976-1977 derived by Appledorn (1982) yielded a slope (Z) estimate of 0.45 (SE=0.06). The conventional theory of fishing partitions total mortality rate (Z) into components due to fishing (F) and natural losses (M). It is the former that is relevant to assessing the impacts of harvesting however an independent estimate of M is needed to compute F by subtraction (F=Z-M).

Estimates of Natural Mortality Rate from Life History Attributes and Un-fished Age Structure- It is well known that the natural mortality rate (M) of animals is related to species longevity. Simple demographic theory requires that long-lived animals have a low annual expectation of death while short-lived animals have greater probabilities of death on an annual basis. Gibson (1999) used several approaches to bound estimates of M for quahogs in Narragansett Bay. The Hoenig (1983) meta-analysis of natural mortality rates produced an equation relating M to species longevity:

$$M= 4.306*T_{max}^{-1.01} \qquad (3)$$

where: M= instantaneous natural mortality rate per year
T_{max}= maximum age of species.

Soft-shell clams do not live as long as quahogs. Appledorn's extensive data for Rhode Island indicate a maximum age of 12 years. By eq. 3, M is estimated to be 0.35 per year. Pauly (1980) also conducted a meta-analysis of M rates and derived a regression relationship for M based on environmental attributes and growth rates for 175 species. His equation was:

$$\text{Log } M= -0.0066-0.279*\log L_\infty+0.654*\log k+0.463*\log \overline{T} \qquad (4)$$

where: $\underline{M}$= natural mortality rate per year
T= mean environmental temperature C
L_∞, k= as defined above.

Appledorn's (1982) findings that *Mya arenaria* exhibits a latitudinal growth gradient suggest that eq.4 is especially appropriate. Mean water temperature in the Rhode Island area is well known from weekly and monthly sampling during DFW and URIGSO trawl cruises. Given L_∞ =86.0, k=0.19 and mean water temperature =11.5, eq. 4 estimates M at 0.29. The final estimate for M was made using a particular useful sample from Appledorn (1982). One of his 1977 sample stations was in Allen Harbor, which at the time was an anchorage site for US Navy vessels and subject to little exploitation (Ganz and Sisson 1977). The age structure of *Mya* then present was therefore likely representative of natural mortality only. A catch curve fitted to these data estimated M at 0.20 with a standard error of 0.05. For further analysis of Potter Pond clams the average M value from the three methods (0.28) was used.

Estimates of Fishing Mortality Rate- Given M=0.28 and the estimates of total mortality rate (Z) from age composition analysis above, fishing mortality rates (F) by subtraction are as follows:

Potter Pond 2005,	F=0.21
Potter Pond 2000,	F=0.18
Rhode Island 1976-77,	F=0.17.

The available data indicate that the intensity of fishing has increases slightly in Potter Pond since the 2000 survey and is above levels that occurred on soft-shell clams in Rhode Island in 1976-1977 when over-fishing was reported in Potter Pond (Baczenski et al. 1979). In fact the Baczenski et al. (1979) report recommended imposing the daily possession limits now in place as a means to curb over-harvest.

Fishing Mortality Rate and Biological Reference Points- Modern fishery management should be precautionary and utilize target and limit reference points designed to provide for long-term resource stability and fishery sustainability (Sandifer and Rosenberg 2005). Limit reference points should never be exceeded and target reference points should be set somewhat below the limit to account for uncertain science and management errors. Gibson (1999) estimated fishing mortality reference points for the Narragansett Bay quahogs (hard clams) using a biomass dynamic model. Updated versions of the model indicate that the limit fishing mortality rate for maximum sustainable yield is F=0.23 (DFW 2005). Under the precautionary approach, a target F rate of 0.18 is recommended. Although a rigorous analysis of soft-shell clam reference mortality rates has not yet been done, the quahog standards can serve as an interim proxy. Potter Pond soft-shell clams would not be subject to over-fishing since the current mortality rate of F=0.21 is less than the proxy limit of 0.23. Although current mortality is close to the limit, there are reasons to believe that soft-shell clams can sustain higher exploitation than quahogs. Robertson (1979) showed that P/B ratio in bivalves and gastropods was an inverse power function of longevity (Figure 6). P/B is the amount of production per unit of biomass by a population and is a dynamic property allowing for yield from a fishery (Chapman 1978). Surplus production, or the amount of biomass produced above that lost to natural mortality, is the yield that a fishery can remove while maintaining the population at a constant level (Hilborn and Walters 1992). Robertson's relationship indicates that an animal like *Mya arenaria* with longevity of about 12 years should have nearly twice the P/B ratio of *Mercenaria mercenaria*, the quahog that can live in excess of 30 years. A target mortality rate for *Mya* might well be on the order of F=0.30 and well above any F estimates past or present. Given the above, it is unlikely that over-fishing is occurring on soft-shell clams in Potter Pond. This conclusion does not rule out the possibility that localized depletions and user conflicts are occurring.

Recruitment Rate, Abundance, and Fishery Landings Trends- The size composition data examined above for Potter Pond as well as samples taken during the 2003 Greenwich Bay fish kill event suggest that soft-shell clams are experiencing a period of high recruitment. Newly settled clams were in very high abundance in the 2005 Potter

Pond samples but not so in 2000 (Figure 7) although methodological improvements in sampling the smallest clams may have exaggerated the difference. Moreover, Fish and Wildlife biologists estimated that more than 1 billion new clams were lost in the 2003 kill event but this was likely only a small portion of a new set in Greenwich Bay. Other recent winterkill events in the Conimicut Point area also indicate high abundance of new clams in upper Narragansett Bay. The periodic Fish and Wildlife surveys of Potter Pond indicate that soft-shell clam abundance is at an all time high (Figure 8). It is not known why bay wide productivity has increased but the commercial fishery is capitalizing on it. Since 2000, commercial landings of soft-shell clams have increased 3 fold as these heavy sets have grown to legal size (Figure 8). Under temporary conditions of high juvenile clam production, depletion by the fishery is unlikely as removals are quickly replaced by growing clams.

Shellfish Management, Applicable Law and Regulation, and Recommendations- The RI general assembly has vested management authority for shellfish in the state with the Director of the Department of Environmental Management (RIGL 20-1-2). The Director is required to consult with and consider the advice of the RI Marine Fisheries Council while exercising said authority (RIGL 20-1-5.1 and 20-2.1-10). Minimum size and harvesting method restrictions on soft-shell clams are given in 20-6-11, 20-6-15 and 20-6-30. Other fishery management elements of Title 20 lay out a set of standards that among other things, requires the Director to develop conservation and management measures that prevent over-fishing and that are based on best available science (RIGL 20-2.1-9). Importantly, the Director may designate certain areas as shellfish management areas to facilitate management of shellfish resources (RIGL 20-3-4).

In keeping with statute, DEM has designated Potter Pond as a shellfish management area and promulgated a number of regulations that govern the harvesting of soft-shell clams as follows:

> General- A 1.5” minimum shell length, prohibition on night fishing, prohibitions on mechanical harvesting and use of scuba.
>
> Recreational- One peck per day possession limit for residents and ½ peck per day limit for licensed non-residents.
>
> Commercial- Three bushels per day possession limit for licensed commercial fishers.

The 2005 DFW survey and assessment of Potter Pond soft-shell clams, like the DFW (2005) shellfish sector management plan, found no evidence of over-fishing. Fishing mortality rate was below the over-fishing threshold and abundance was high. Soft-shell clams are in a period of high productivity that has triggered increased commercial activity. At this point, current regulations seem to be sufficient to maintain a sustainable fishery. Given the increased commercial activity however, regular monitoring and surveys are warranted in Potter Pond and all Rhode Island waters. DFW conducts annual resource surveys and is improving fishery monitoring through implementation of the

SAFIS dealer reporting system. Together, these programs will greatly improve management of shellfisheries in the state by providing spatially explicit information on fishery landings and shellfish abundance. Spawner sanctuaries and rotational harvest strategies are a fundamental element of the DEM/DFW quahog management plan (Ganz et al. 1999). The sanctuaries are designed, in concert with pollution closures, to maintain sufficient spawner biomass nearby harvest beds. Currently, there are no spawner sanctuaries or pollution closures in Potter Pond. It may be possible to configure a sanctuary in Potter Pond that mitigates the impact of increased harvesting as well as reducing user conflicts. These and other measures should be considered as DFW and the Marine Fisheries Council advance the management of soft-shell clams in the state.

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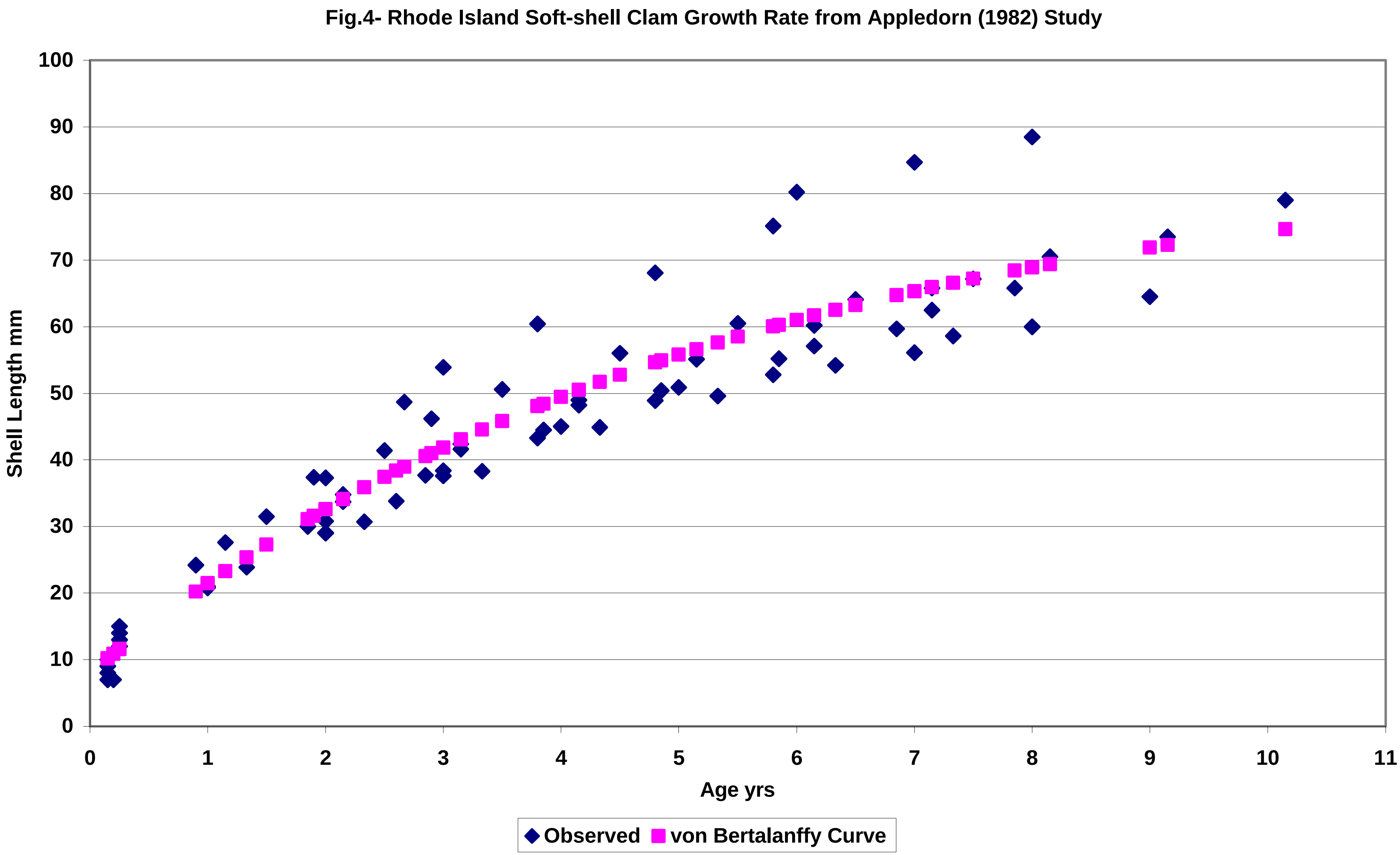


Fig.4- Rhode Island Soft-shell Clam Growth Rate from Appledorn (1982) Study
Shell Length mm
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
Age yrs
Observed
von Bertalanffy Curve

Fig.5- Estimated 2005 Age Structure of Potter Pond Soft-shell Clams and Fitted Catch Curve to Legal Sizes

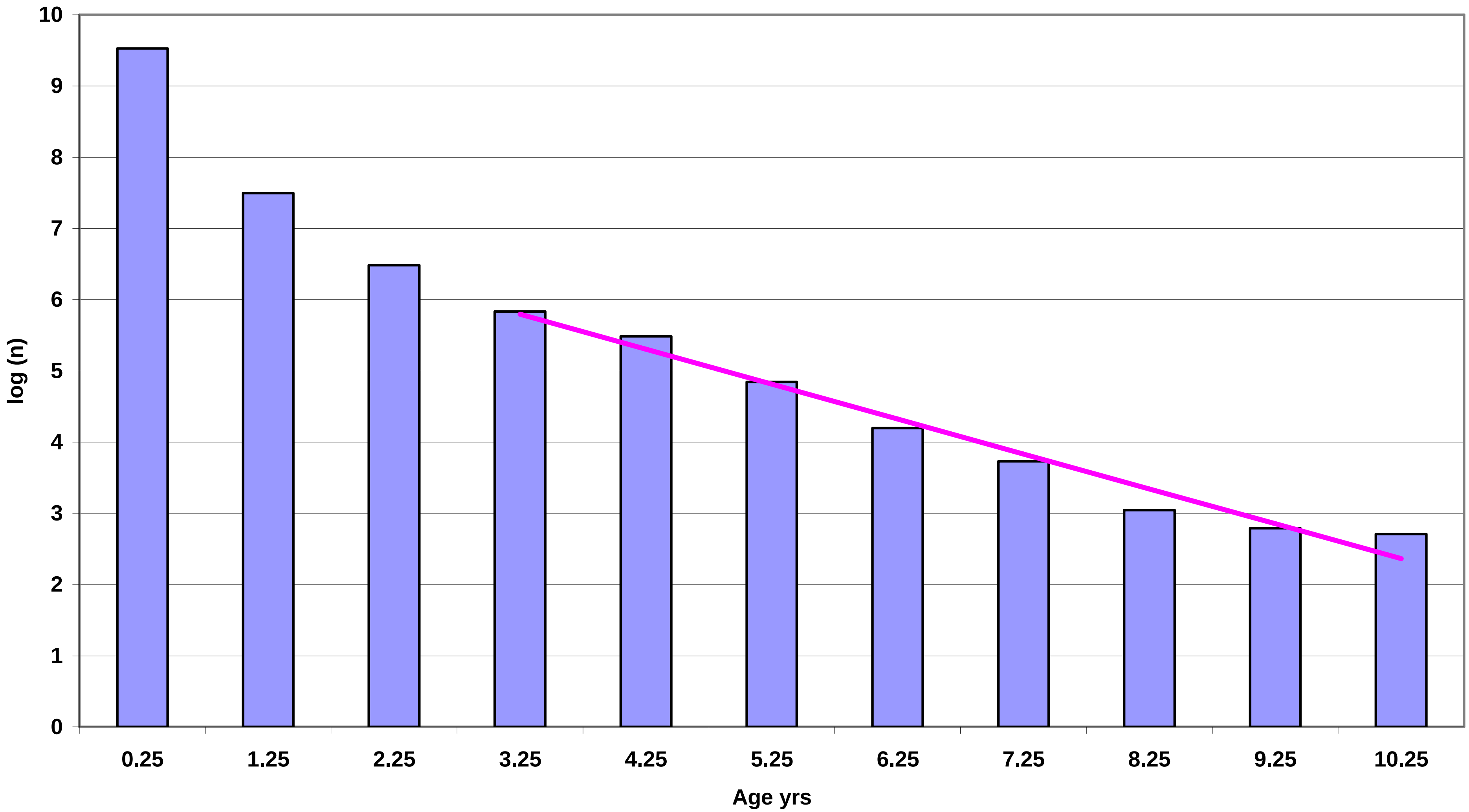


Fig. 6- Production to Biomass Ratio vs. Longevity in Bivalves and Gastropods from Robertson (1979)

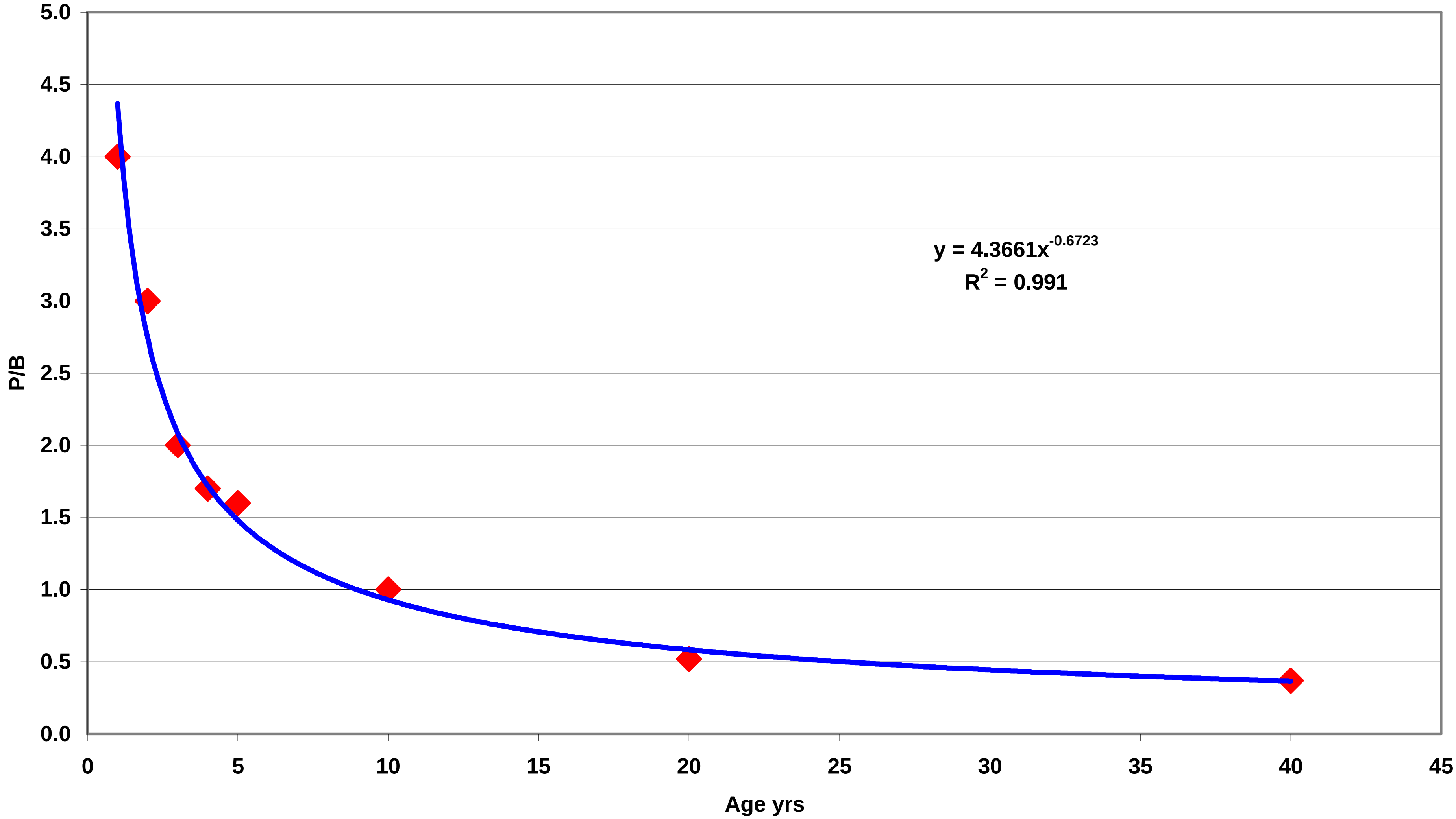
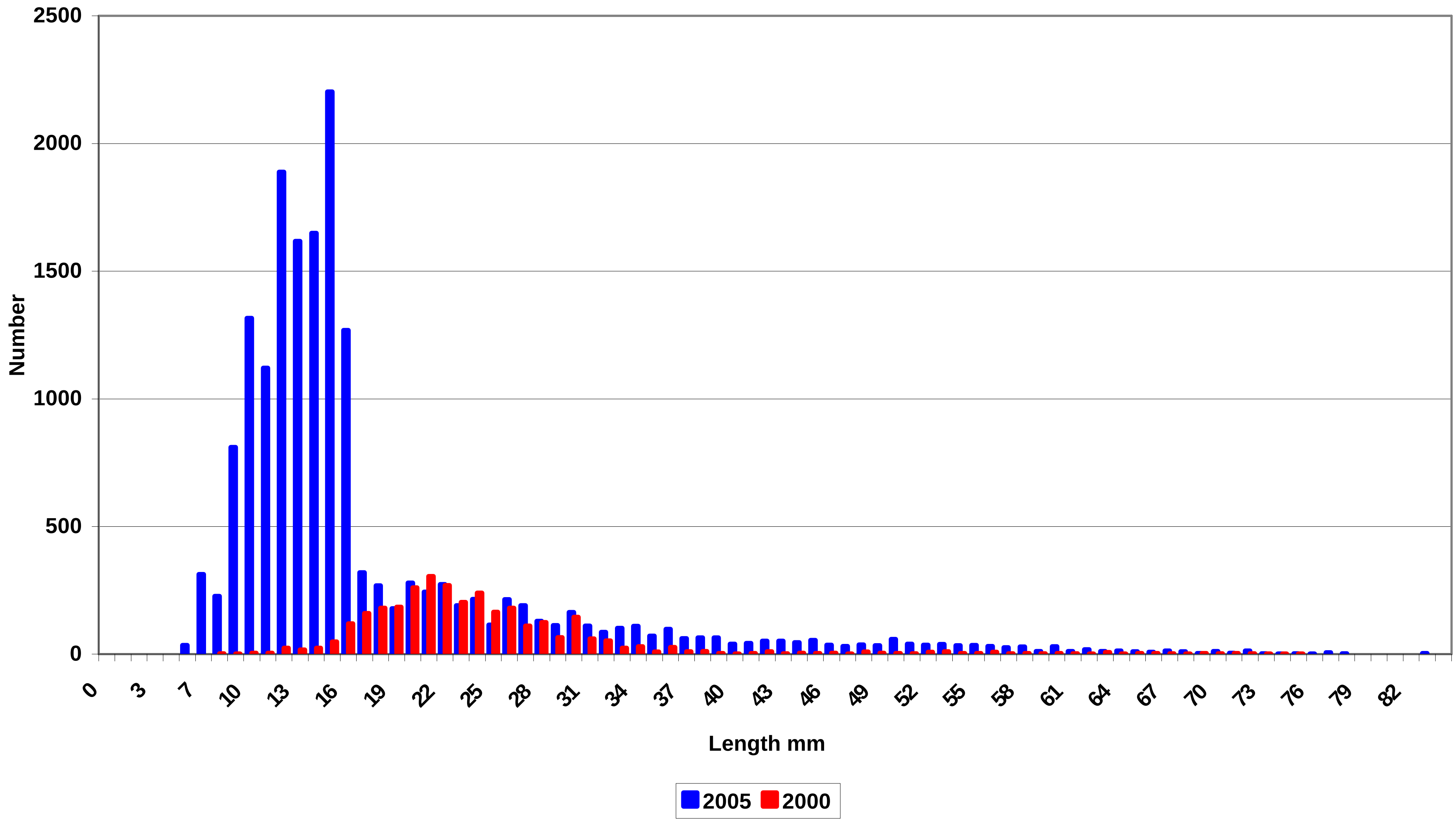


Fig.7- Comparison of 2000 and 2005 Potter Pond Soft-shell Clam Size Distribution



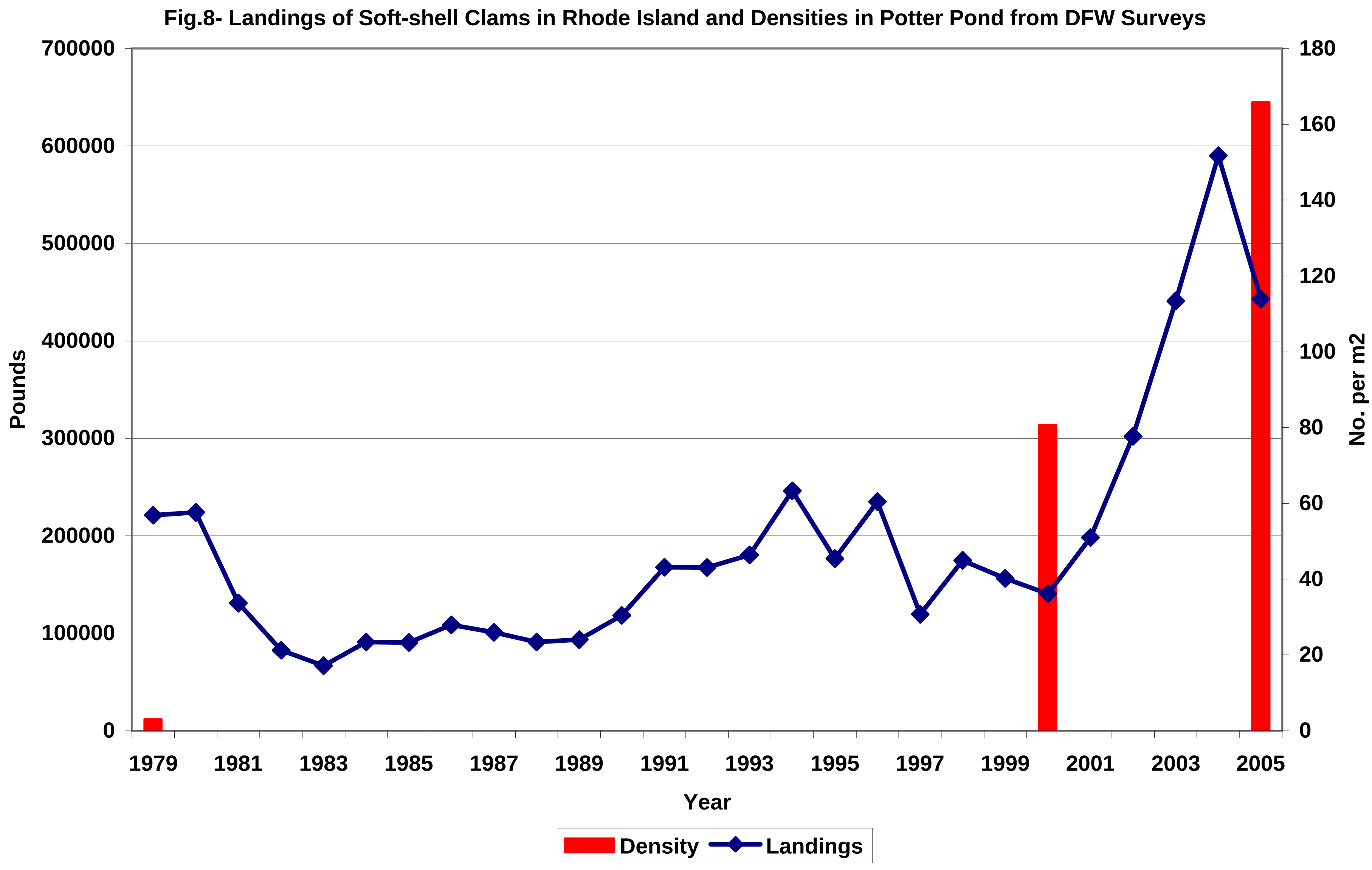


Fig.8- Landings of Soft-shell Clams in Rhode Island and Densities in Potter Pond from DFW Surveys
700000
600000
500000
400000
300000
200000
100000
0
Pounds
180
160
140
120
100
80
60
40
20
0
No. per m2
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year
Density
Landings